THE JOURNEY TOWARDS DUST REDUCTION AND OFF-GROUND HARVEST

Brian Wahlbrink, *Sperry Farms*

Sebastian Saa, *Almond Board of California*

Guangwei Huang, *Almond Board of California*

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The Journey Towards Dust Reduction and Off-Ground Harvest

Agenda

1.	Opening remarks from our Harvest workgroup chair	Brian Wahlbrink, Sperry Farms
2.	The journey towards dust reduction and off-ground harvest	Sebastian Saa, Associate Director, ABC
3.	Reducing barriers of adoption: Drying almonds	Guangwei Huang, Associate Director, ABC
4.	ABC Video: Journey towards dust reduction	Brian Wahlbrink, Sperry Farms

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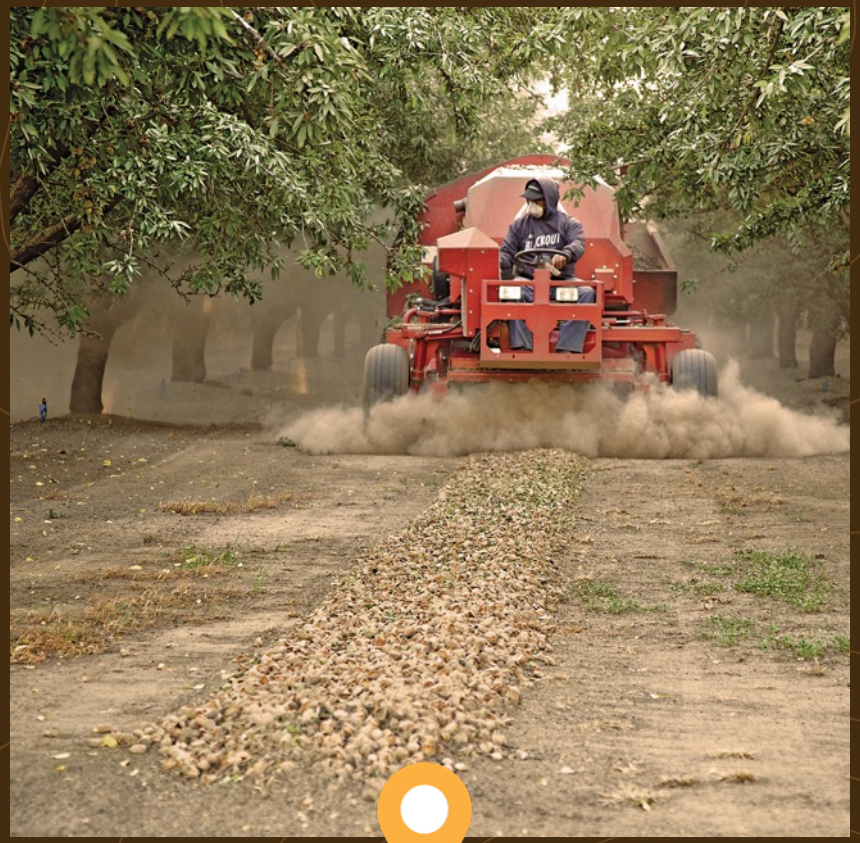
Water
harvest dust
ALMOND
ORCHARD
2025 GOALS
pest management
zero Waste

air quality

"**Reduce dust** during harvest by 50%"

PAST



PRESENT

FUTURE

Harvest workgroup

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Especial thanks to our workgroup members!

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Sebastian Saa, *Almond Board of California*

The journey towards dust reduction and off-ground harvest

Sebastian Saa, Associate Director, ABC

Dust reduction roadmap

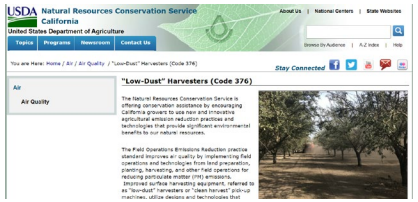
ABC sponsored research in harvest dust started in the 2000s and continues to play a key role in moving our industry forward

2015

Threshold: 30% reduction in PM10 emissions compared to Flory 480

Payment: $38.93/acre

NRCS Incentive



2016

Harvest BMPs:

Pre-harvest

Sweeping

Pick-up

Visit Almonds.com to learn more about these resources!

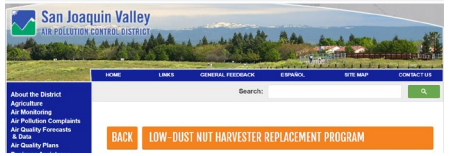
Harvest Dust- BMP resources

2018

Threshold: 40% reduction in PM2.5 emissions compared to Flory 480

Payment: 50% of new equipment

San Joaquin Valley Air Pollution Control District



2018

Harvest workgroup embraces Orchard 2025 goals

Harvest workgroups develops a strategic research plan

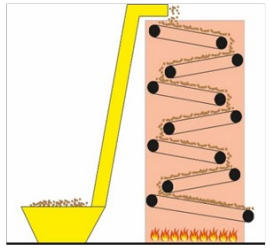
Research in off-ground harvest starts

Shake and Catch and Hull

2020

Research projects begin to yield outputs around economic costs, windfall and drying options under off-ground harvest

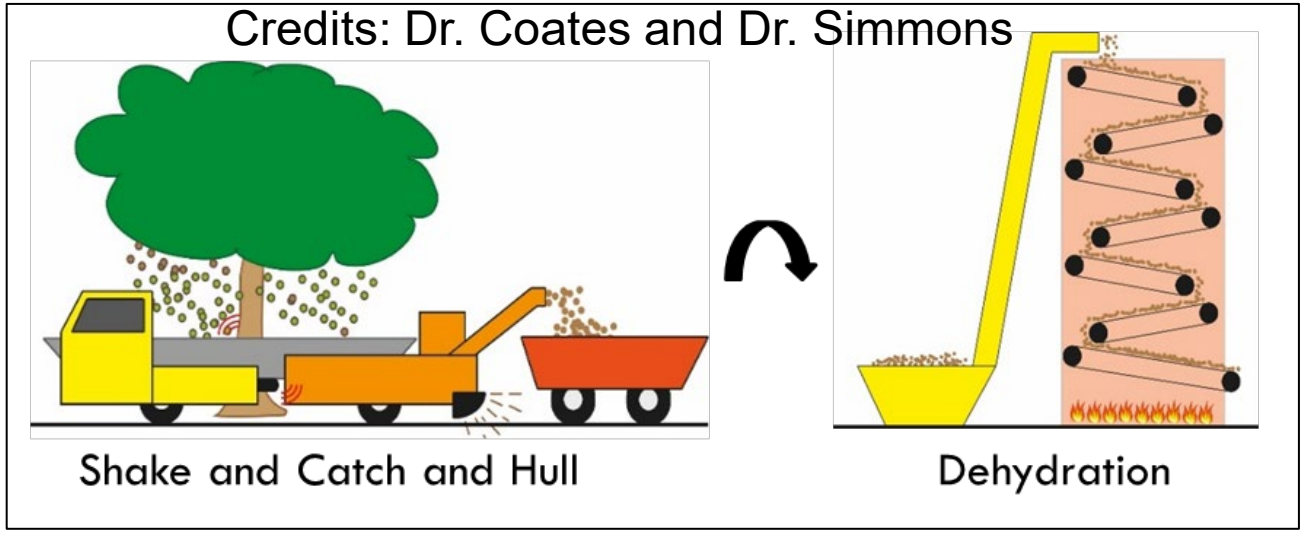
Adoption of semi off-ground harvest begins



Dehydration

Potential benefits of off-ground harvest

- Dust reduction
- Less herbicide use
- Less NOW damage and mite damage
- Improvements in soil health
- Reduction of tree water stress
- Fewer field passes



- Reduction of food safety risks associated with orchard floor contact
- Reduction of exposure or contamination from pesticides and herbicides
- Improvements in almond quality by working with a more homogeneous product and controlled drying conditions

Barriers of adoption for off-ground harvest

- Economic viability study
- Windfall
- Stockpiling and mechanical drying
- Orchard configuration

Strategic Research Plan: **Updated after harvest workgroup meeting on 6/26/18**

By 2025, the California almond community commits to reduce dust during almond harvest by 50%

Harvest 2018
RFP 2017.18

- Techno - Economic analysis

Harvest 2019
RFP 2018.19

- Windfall
- Drying
- Processing
- Leverage
- Visible dust

Harvest 2020
RFP 2019.20

- Windfall
- Drying
- Processing
- Equipment test
- Leverage
- Visible dust

Harvest 2021
RFP 2020.21

- Horticultural Benefits
- Drying
- Processing
- Equipment test
- Leverage
- Equip. dev.?

Harvest 2022
RFP 2021.22

- Horticultural Benefits
- Drying
- Processing
- Equipment test
- Dust measurements
- Leverage
- Equip. dev. ?

Harvest 2023&24&25
RFP 2022.23&24&25

- TBD based on previous year results

Latest outputs

- **Dr. Simmons:** “economic models showed the potential for increased profitability for growers of up to $200 per acre – along with varying degrees of dust control – across different shake-and-catch harvesting scenarios.
    - Reduction in operational costs mainly due to fewer orchard and cultural practices: Eliminate blower and sweeper, eliminate ant control, run two instead of six mowing operations, eliminate dormant strip spray, and eliminate pre-harvest spray for weed management.

- **Dr. Brown**: Results in 2019 showed 0-1% windfall, with most orchards at less than 0.4% windfall. 2020 results are under analysis, but windfall is expected to be greater in certain locations due to significant changes in weather conditions.

- **Dr. Pan’**s research results showed that the cost to mechanically dry a pound of almonds can range from 0.06 cent to 5 cents, depending on the drying method.

- **Dr. Pan** developed a protocol for velocity and air flow for mechanical drying that, when used correctly, results in better, more consistent moisture content of the end product compared to conventional, passive drying.

- **From Dr. Pan and Dr. Brown**’s preliminary hypotheses and results: With off-ground harvesting, there’s a higher probability for reduced Navel Orangeworm damage because the fruit is no longer drying in the orchard, eliminating NOW’s opportunity to feed on the kernels.

THE JOURNEY TOWARDS DUST REDUCTION AND OFF-GROUND HARVEST

Guangwei Huang, *Almond Board of California*

Alternative Ways to Dry Almonds

Guangwei Huang
Associate Director, Food Research and Technology

Almond Annual Conference

December 9, 2020

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Off-ground Harvesting Requires More Drying Alternatives

- Conventional harvest – Dry inhull almonds on ground for 7 to 14 days
- ABC 2025 Goal for Harvest – Reduce dust during harvest by 50%
- Some adoption of off-ground harvest may be needed
- More drying mechanisms are needed for off-ground harvesting
  - Windrow drying to skip sweeping
  - Dry on solid or leveled open ground
  - Mechanical drying away from orchards: hot air, ambient air, etc.

Exploratory Drying of Freshly Harvested Inhull Almonds

Control

Windrow

Pothole Bin Drying

Stockpile Aeration

Concrete Ground

- **Pothole bin drying**: Bottom door metal bins loaded with 4 feet depth of inhull nuts, repeated cycle of 105°F hot air blowing and ambient air conditioning, top exit air flow ranged 0.7 to 1.5m/s.
- **Stockpile aeration**: 6 to 7’ x 20-25” inhull piles on 6 feet long of perforated pipe with 1/5 HP carpet blower
- **Concrete ground:** 2 to 3 inches product loading depth without raking
- **Windrow**: Double layers of nuts on breathable paper tarp in the middle of tree rows
- **Control**: Conventional orchard floor drying alongside the tree row

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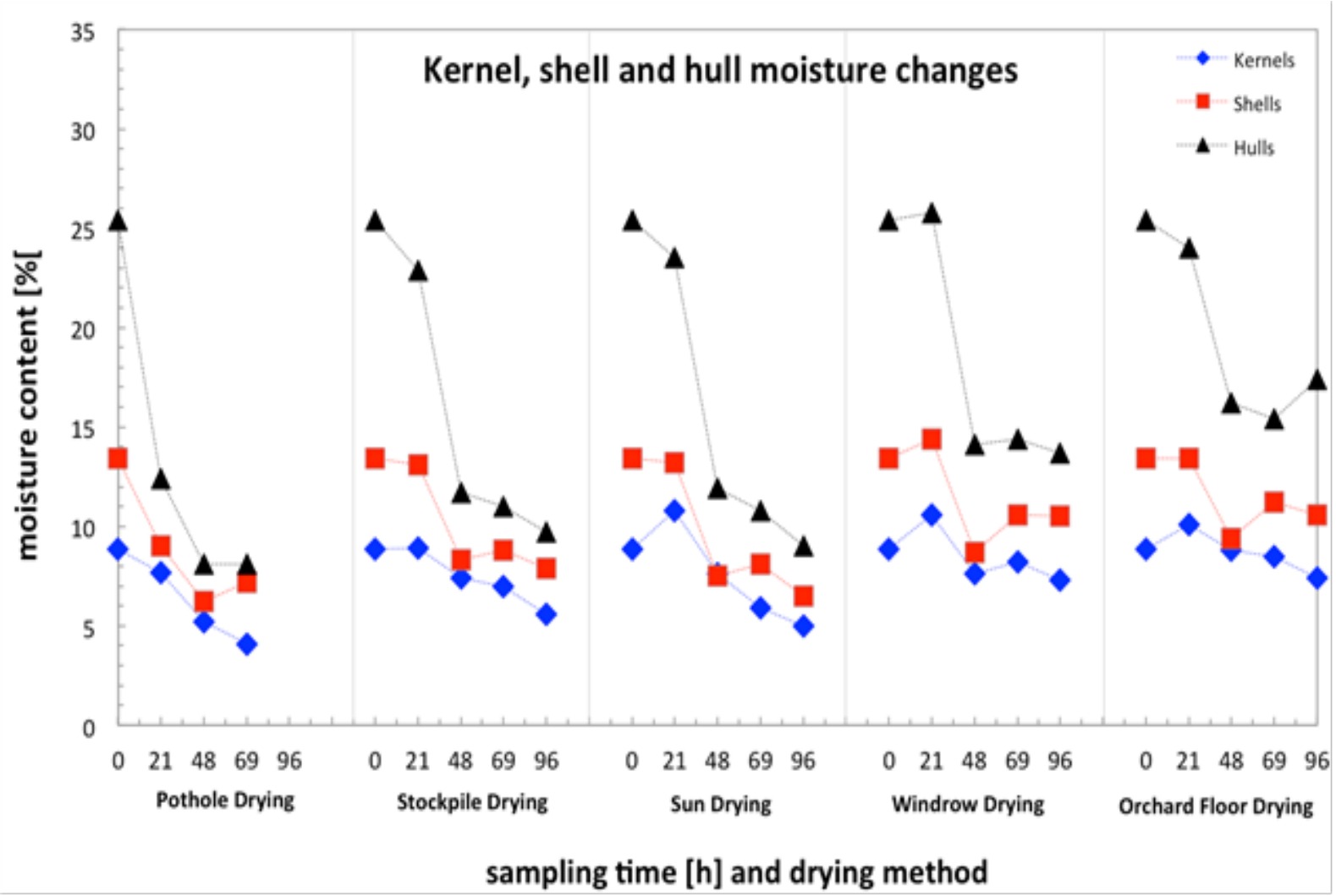
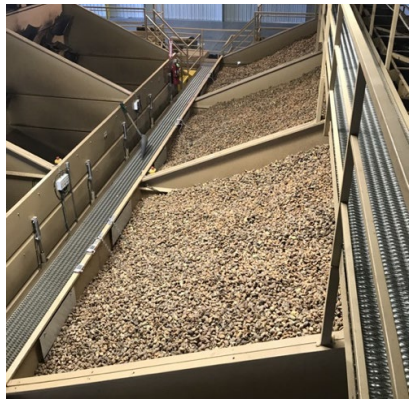
Artificial Drying Methods Shortens Drying Time



- **Pothole Bin Drying**: Reached MC < 6% within 1 day
  - 2 cycles of air blowing of 5 hours 105°F hot air and 1-hour ambient air
- **Stockpile Aeration**: Reached MC < 6% within 4 days
- **Sun Drying**: Reached MC < 6% in < 3 days
- **Windrow and Floor Drying**: > 6 days to reach MC < 6%

Many Commercial Dryers Used by Other Industries

Commercial Dryers Dry Inhull Almonds from Regular Harvest Moisture (10 - 13%) to < 6% in 9 to 18 hours



- Stadium Drying
- Dimension: 10 ft x 11 ft x 8 ft
- Capacity: 8 tons
- 95 ºF & 1.2 m/s
- 16.9 hours from 12.7% to 3.9% kernel MC

- Column Drying
- Capacity: 5,200 ft^3
- 125 ºF & 15 kw fan
- 18 hours from 10% to 4% kernel MC

- Tunnel Drying
- Dimension: 10 ft x 10 ft x 6 ft
- Capacity: 22 tons
- 115 ºF & 1 m/s
- 12.9 hours from 12.9% to 5.8% kernel MC

- Trailer Drying
- Dimension: 28 ft x 8 ft x 7 ft
- Capacity: 23 tons
- 138 ºF & 1.2 m/s
- 9 hours from 12.9% to 5.0% kernel MC

Drying Performance of Commercial Dryers (2019 and 2020)

- Initial and final moisture affect performance
- Drying time decreased with hot air temperature
- Energy consumption increased with the increase in hot air temperature
- Specific energy consumption ranged from 1.2 to 6.9 MJ/kg water removal
- Less than 2 cents per pound of dried kernels from regular harvesting moisture level

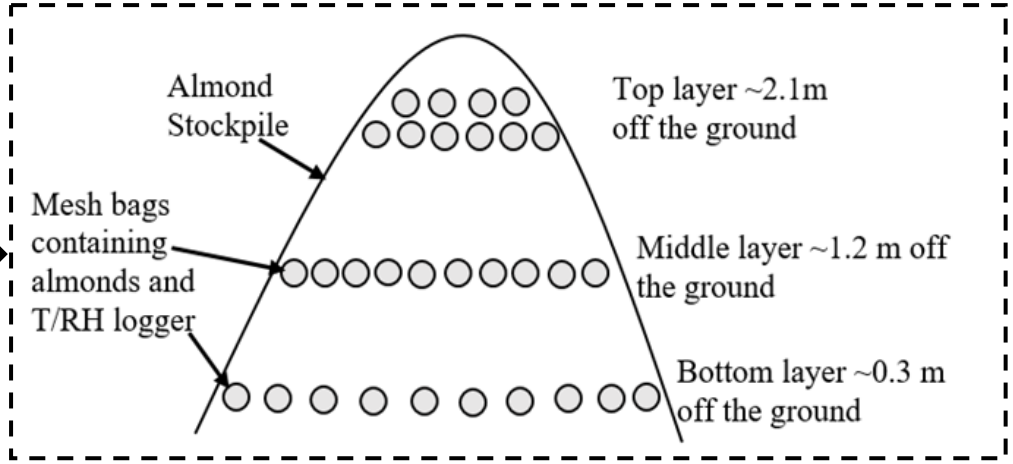
Drying condition	Variety	Initial MC (%)		Final MC (%)		Drying time (h)	Specific energy consumption (MJ/kg)	Energy Cost (cents/lb)
		Whole	Kernel	Whole	Kernel			
Tunnel -Ambient	ID	37.6	12.9	17.4	7.9	49.7	1.25	1.02
Tunnel -115°F				12.5	5.8	12.9	6.91	1.29
Stadium-95°F	MT	24.4	12.7	7.8	3.9	16.9	2.80	0.54
Stadium-95°F	FR	44.3	17.7	6.5	3.8	48.0	3.35	2.00
Trailer-110°F	MT	20.0	8.0	8.3	4.8	6.5	1.2	0.17
Trailer-130°F				7.7	4.1	5.8	2.8	0.39
Trailer-Ambient	NP	34.4	12.0	7.5	3.8	74.4	0.67	0.31*
Trailer-142°F				13.9	7.7	9.4	2.29	0.35*
Trailer-162°F				9.7	5.2	6.8	4.91	0.55*
Trailer-133°F	WC	57.4	26.6	4.7	2.9	40.9	3.96	2.13*
Trailer-149°F				6.0	3.3	25.3	5.37	3.20*
Trailer-122°F	MT	32.4	16.5	8.5	5.1	17.8	3.65	1.03*
Trailer-138°F		24.3	12.9	8.1	5.0	9.6	3.45	0.49*

*on inhull nut weight basis

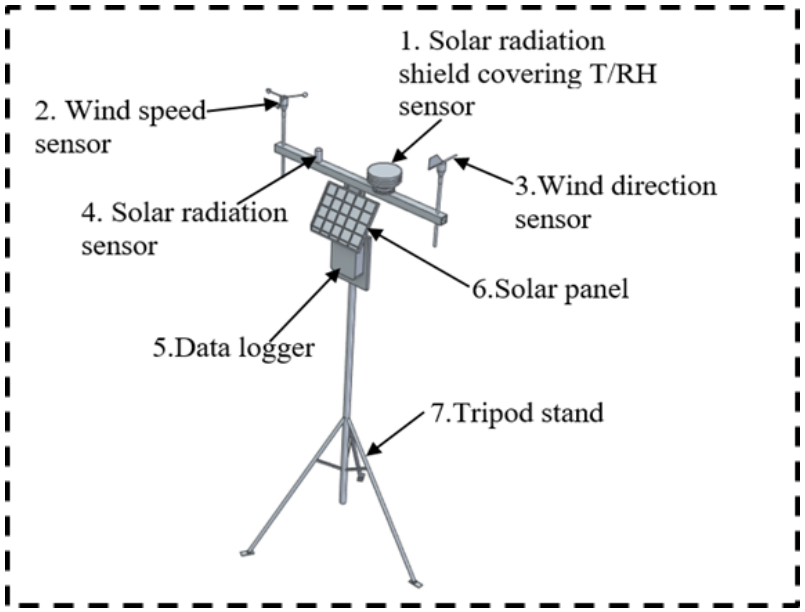
In-field Drying Through Stockpile Aeration

4,155 kg Fresh Almond Stockpile

T/RH loggers in the stockpile to record Temperature, Relative Humidity



Weather Station to record ambient conditions



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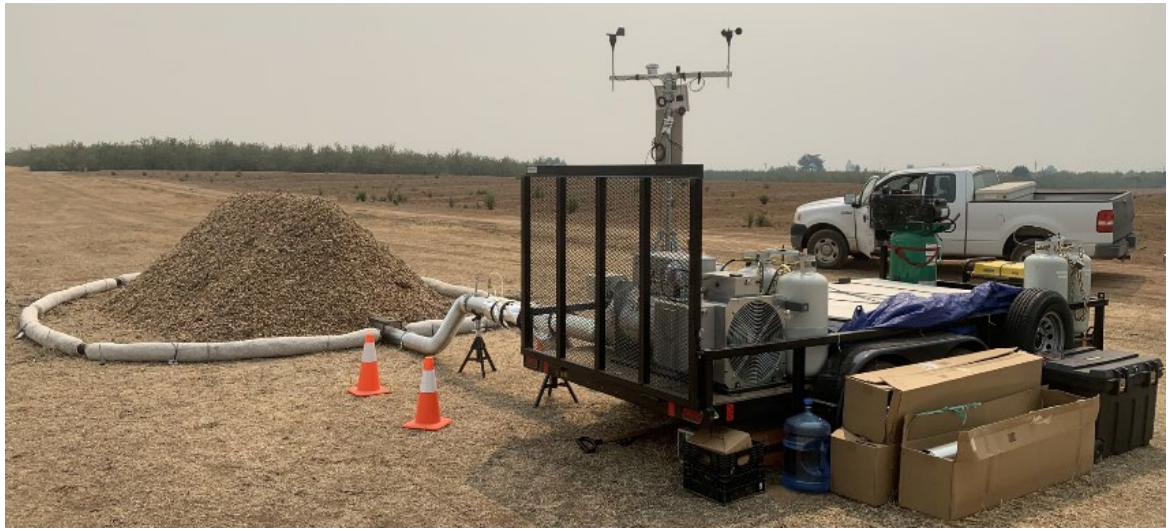
In-field Stockpile Drying May Take as Long as Conventional Harvest



- Long drying time (11-15 days)
- Non-uniformity of drying – high MC from bottom section, low MC from top section
- Stockpile size and fan speed need to be optimized
- Ambient air flow, temperature and humidity showed impact
- Costs US$11.65/MT (0.5 cents per pound) of dried inhull almonds

2020 In-field Stockpile Drying Trials

Variety	Pile Dimension (ft)	Inhull Almond Weight (lb)	Kernel Initial MC (db)	Kernel Final MC (db)	Drying Time (days)
Nonpareil	16x12x5.1	10,500	11.83	4.45	15
Winter	12x8x5	5,700	11.60	4.64	11
Monterey	24x16x5.1	15,100	21.49	4.54	14

Ambient Aeration Drying Time May be Shorten under Contained Conditions

NP: MC 12.9% → 49.7 hours, Air 1 m/s → 7.9%

NP: MC 12.0% → 74.4 hours, Air 1.2 m/s → 3.8%

Stockpile Drying Needs Optimization at Large Scale

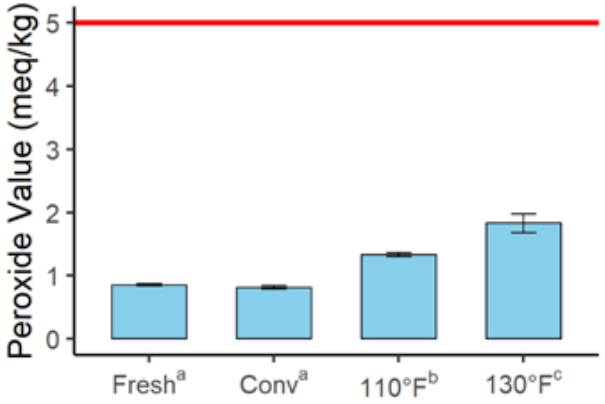
- Many parameters to be studied
- Commercial scale with more variable speed powerful fan
- Proper air velocity for stockpile size
- Air flow distribution channels
- With/without tarp to regulate air flow

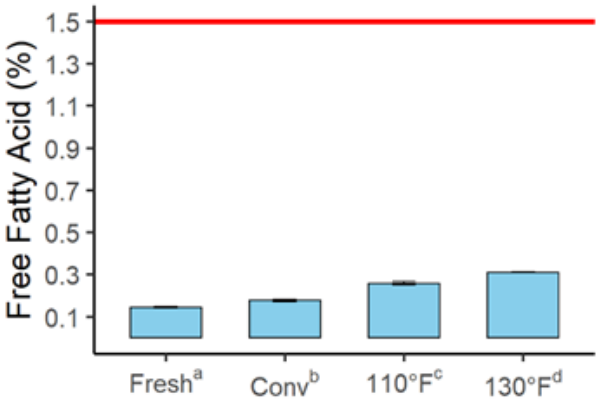
Drying Did Not Impact Quality

- Constant temperature drying up to 140°F shows no negative effects on quality
- Color (Whiteness Index)
  - No significance change vs. fresh harvested almonds (Control)
  - No significant difference vs. conventional harvest and drying (Conv)
- No cavity observed for all samples from commercial drying
- No concealed damage for all samples
  - CDS < 3.0
- PV and FFA were similar to the conventional on-ground drying (MT)
  - Increased with the increase in temperature
  - Much less than the industrial limit (PV < 5 meq/kg, FFA < 1.5%)

Trailer dried kernels after roasting

Kernel color after trailer drying





PV and FFA of extracted almond oil (trailer drying, MT)

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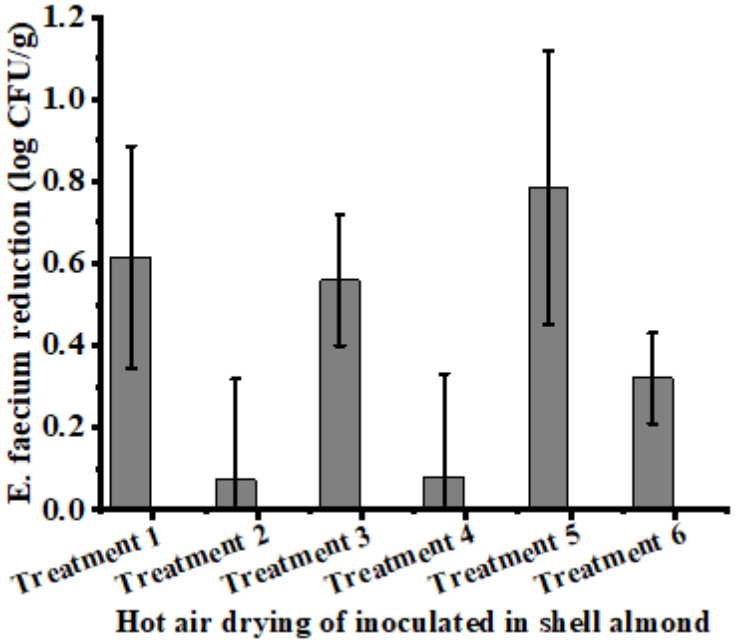
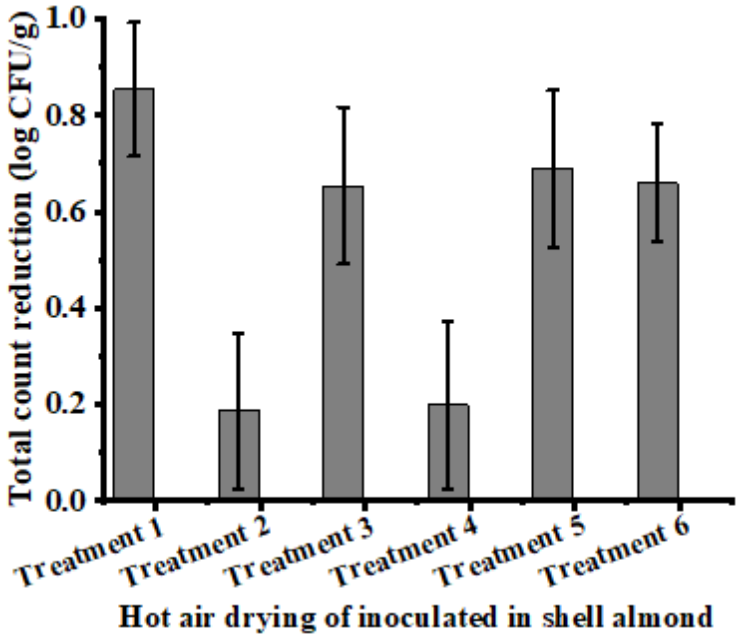
Stepwise High Temperature Drying Has Shown Effects on Disinfestation and Disinfection

- Stepwise drying with high temp up to 194ºF and held for 3 hours then at 140ºF to finish drying
  - Wet hulls appear to tolerate heat well
  - Stepwise drying did not reduce drying time
  - More effects on disinfestation
- Energy consumption:
  - Energy consumption and energy cost decreased with the increase in the holding time in general
- Product quality
  - No color change (kernel whiteness) or cavity developed
  - No concealed damage (CDS < 3.1)
  - Good oil quality: PV (< 0.7 meq/kg) and FFA (< 0.37%) of almonds after column drying were similar to conventional drying (PV: 0.998 meq/kg and FFA: 0.23%)





Reductions in the Rif-resistant *Enterococcus faecium* level and total count on PCA for inoculated in-shell almond
Notes: Treatment 1: 194°F-1h-140; Treatment 2: 194°F-2h-140; Treatment 3: 194°F-3h-140;Treatment 4: 176°F-1h-60; Treatment 5: 176°F-2h-140; Treatment 6: 176°F-3h-140;

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Drying Off-Ground Harvested Almonds Reduce Insect Damage Levels by Up to 6.7 Percentage Points

Year	Variety	Days on ground	Insect infestation (%)	
			Conventional	Off-ground
2019	NP	11	6.3	3.3
	MT	14	11.4	6.3
	FR	9	4.5	2.5
	ID	10	10.0	3.3
2020	NP	14	3.1	1.5
	WC	19	2.0	0
	MT	15	6.0	5.0

- Less insect damage and cleaner from off-ground harvest
- Off-ground harvested almonds in different maturity stages
- Drying can eliminate infestation and reduce microbial load by 0.8 logs

Off-ground harvested almonds

Conventional harvested almonds

Variety	Drying conditions	Insect infestation percentage(%)
Nonpareil	On-ground drying	3.1
	Ambient	1.9
	40°C	1.2
	50°C	0.6
	60°C	0.5
	80°C~1h~60°C	0.6
	80°C~2h~60°C	0.5
	80°C~3h~60°C	0
	90°C~1h~60°C	0
	90°C~2h~60°C	0.4
	90°C~3h~60°C	0

Conclusions and Next Steps

- Almonds from off-ground harvest vs. conventional harvest
  - Less insect damage and cleaner
- Existent commercial dryers can be used inhull almond drying
  - Drying can be achieved in 6 to 48 hours varying with initial moisture levels and drying conditions
  - Drying temperature up to 140°F showed no impact on quality
  - Drying costs less than 2 cents per kernel pound
- Stepwise high temperature hot air drying with holding
  - Similar product quality compared to conventional on-ground drying
  - Complete disinfestation and some disinfection effects
  - Recommend conditions: 194ºF holding for 1 h then finish at 140ºF, 1 m/s
- Next Steps:
  - Harvest timing and handling logistics (drying inhull or inshell almonds or leave loose hulls out?)
  - Higher temperature for trailer drying should be tested
  - Large scale stockpile drying parameters
  - More drying technologies

Acknowledgement

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  - West Valley Hulling Company
  - Wizard Manufacturing Inc.
  - Nickels Soil Lab
  - Australian almond growers
  - Off-ground harvester equipment companies

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Thank You


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